ENGINEERING PEER REVIEW
PERIPHYTON-BASED STORMWATER TREATMENT AREA (PSTA)

Prepared for

South Florida Water Management District
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March, 2002

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EXECUTIVE SUMMARY

The District and other parties are engaged in the research and demonstration of Advanced Treatment Technologies (ATTs) that may be used alone or in conjunction with stormwater treatment areas (STAs) for achieving the long-term water quality goals of the Everglades Program restoration effort. A total of eight ATTs are being evaluated.

To enable the District to provide a scientifically defensible basis for comparative evaluation of the successful technologies, a Supplemental (Advanced) Treatment Technology Standard of Comparison (STSOC) was established. The STSOC provides an approach to comparing the effectiveness of one advanced treatment technology to another.

This project reviews the STSOC analysis report for periphyton-based stormwater treatment areas (PSTAs) with regard to the following:

- Validity of the conceptual design of full-scale facilities;
- Review of the design assumptions; and
- Verify that the design is conceptually correct and that there are no major errors in the conceptual design.

The PSTA peer review team was selected based on expertise in the general fields of ecology, wetland engineering, and natural system modeling. The team members were chosen by the SFWMD because of their knowledge and experience in the fields most closely related to biological treatment systems.

Following the STSOC Guidelines, the peer review panel found that the PSTA STSOC Report addressed the ten quantitative and qualitative STSOC criteria. However, some issues are brought to attention by our peer review team:

1) Biological steady-state does not seem to be reached for the PSTA cells from which data sets were used for forecasting;
2) These data sets were extrapolated outside the model's limits regarding hydraulic loading, phosphorus inflow concentration and water depth in the PSTA test systems;
3) Model limitations may have resulted in over- or underestimating PSTA size and cost; and
4) Macrophyte and residuals management are not adequately accounted for.

The peer review team's main recommendations are as follows:

- Re-evaluate the biological stability of PSTA systems used to provide modeling and calibration data sets;
- Re-address modeling with the now available DMSTA model;
- Perform a P/R ratio analysis (oxygen used in PSTA photosynthesis versus oxygen used in PSTA respiration) to determine steady-state for PSTAs;
- Provide quantitative information on anticipated side streams (macrophyte and biosludge management). This will be important information for evaluating PSTA operational flexibility and cost. Additionally, the effect of the proposed side-stream management options on PSTA effluent TP concentrations should be described;
- Gain more insight in long-term behavior of the substrate. If this is to be limerock, what effect will the forming of an organic substrate have on TP removal and PSTA operational costs and flexibility?

1 BACKGROUND

Florida's 1994 Everglades Forever Act (F.S. 373.4592) and the federal Everglades Settlement Agreement (Case No. 88-1886-CIV-HOEVELER) establish both interim and long-term water quality goals designed to restore and protect the Everglades Protection Area (EPA). As defined in the Act and the Settlement Agreement, the Everglades Protection Area includes Water Conservation Areas 1, 2A, 2B, 3A, 3B, the Arthur R. Marshall Loxahatchee National Wildlife Refuge, and the Everglades National Park.

Activities are currently underway to meet the interim goal of reducing phosphorus levels in discharges from the Everglades Agricultural Area (EAA) and other sources to the Everglades Protection Area to a long-term annual flow-weighted mean concentration of 50 parts per billion (ppb). These activities include the implementation of Everglades Agricultural Area Best Management Practices (BMPs) and the construction of over 42,000 acres of Stormwater Treatment Areas (STAs) through the Everglades Construction Project (ECP). Concurrent with implementation of the ECP, the District is implementing the Everglades Stormwater Program (ESP) to address the water quality issues associated with discharges from the remaining non-ECP Everglades tributary basins. Also concurrent with these activities, the District and other groups are conducting water quality research, advanced treatment technology research, ecosystem-wide planning (e.g., the Comprehensive Everglades Restoration Plan, or CERP), and regulatory programs to ensure a sound foundation for science-based decision-making.

1.1 Everglades Phosphorus Reduction

The long-term goal of the Everglades Program restoration effort is to combine point source control, basin-level, and regional solutions in a system-wide approach to ensure that all waters discharged into the Everglades Protection Area meet the numeric phosphorus criterion and other applicable state water quality standards by December 31, 2006.

In accordance with the Act, the EPA total phosphorus (TP) criterion shall be 10 ppb in the event the Florida Department of Environmental Protection (DEP) does not adopt by rule such criterion by December 31, 2003. The Corps of Engineers Permit for the Everglades Construction Project requires "For the purposes of planning, 10 ppb (total phosphorus) shall be used as the design parameter pending adoption of the numeric criterion by the Department of Environmental Protection or Everglades Regulatory Commission."

The District and other parties are engaged in research and demonstration of Advanced Treatment Technologies (ATTs) that may be used alone or in conjunction with STAs for achieving the long-term water quality goals for the Everglades. Research teams are evaluating the technical, economic and environmental feasibility for basin-scale application.

Eight ATTs are being evaluated:
- Chemical Treatment - Direct Filtration
- Chemical Treatment - High Rate Sedimentation
- Chemical Treatment - Dissolved Air Flotation/Filtration (DAF)
- Chemical Treatment - Microfiltration
- Low Intensity Chemical Dosing of Wetlands (LICD)
- Managed Wetlands
- Submerged Aquatic Vegetation (SAV)/Limerock
- Periphyton-based Stormwater Treatment Areas (PSTAs)

As a result of the research studies conducted during 1998 and 1999, Chemical Treatment – Direct Filtration, Chemical Treatment – Dissolved Air Flotation/Filtration and Low Intensity Chemical Dosing of Wetlands did not achieve the 10 ppb TP goal, and are not considered viable technologies.

1.2 Supplemental Technology Standard of Comparison (STSOC)

To enable the District to provide a scientifically defensible basis for comparative evaluation of the successful technologies, a Supplemental (Advanced) Treatment Technology Standard of Comparison (STSOC) was established. The STSOC provides an approach to comparing the effectiveness of one advanced treatment technology to another. The STSOC has evolved as follows:

PHASE I: Formulate conceptual approach, development of the Contract Guidance Documents
PHASE II: Development of the evaluation methodology and STSOC database
PHASE III: Development of standardized cost information
PHASE IV: Compilation and evaluation of Advanced Treatment Technology data.

In Phase I, Peer Consultants prepared a concept letter report that proposed twelve evaluation concepts and a Contract Guidance Document (PEER Consultants, P.C./Brown and Caldwell, 1998a). This Contract Guidance Document listed the goals and detailed the specific information on sampling, data management protocol, forms, and formats that each of the Advanced Treatment Technology Demonstration Project Research Teams (DPRTs) needed to follow during data collection.

In Phase II, Peer Consultants refined the evaluation concepts into an evaluation methodology consisting of 10 criteria. The evaluation methodology attempts to provide a basis to compare dissimilar technologies. An STSOC database was developed to serve as a repository for storing DPRT research data, and as a comparative ATT evaluation tool. The evaluation methodology for the data and information collected from the DPRTs consisted of quantitative and qualitative concepts, which are set forth below.

QUANTITATIVE EVALUATION METHOLOLOGY
1) Level of Phosphorus Concentration Reduction
2) Level of Phosphorus Load Reduction
3) Cost-effectiveness
4) Potential toxicity
5) Implementation schedule

QUALITATIVE EVALUATION METHOLOLOGY
1) Uncertainty Assessment of Full Scale Construction, Operations, and Scale-up
2) Operational flexibility
3) Sensitivity to fire, flood, drought and hurricane
4) Level of effort to manage side streams control
5) Other water quality issues

During Phase III, PEER Consultants/Brown and Caldwell developed standardized costing data to serve as the basis for estimating the cost of equipment, land, levees, etc. to be used by each DPRT in developing full-scale treatment facilities. The cost basis will be used with the evaluation guidelines established in previous documents for Phases I and II to make comparisons between the technologies.

During Phase IV, which is scheduled to be completed within the next two years, data from the ATT projects will be compiled, evaluated and compared.

One of the final deliverables from the demonstration project research teams will be a report summarizing the research results, including a conceptual-level layout of a full-scale treatment system designed to treat the flows and phosphorus loads into and out of STA 2 for the period 1979-1988 (Period of Record or POR). Conceptual estimates of capital and annual operation and maintenance costs will be included in this report, as will preliminary implementation schedules.

2 PROJECT OBJECTIVE

Under SFWMD Contract C-E018, Work Order #12, PB Water was tasked with conducting a peer review of the STSOC analysis of the PSTA research and demonstration project.

2.1 Peer Review Document

Peer review was conducted on the following document:

> "PSTA Research and Demonstration Project (C-E8624): Draft Supplemental Technology Standards of Comparison (STSOC) Analysis; Conceptual Designs and Planning Level Cost Estimates for a Full-Scale Periphyton Stormwater Treatment Area (PSTA)", prepared for South Florida Water Management District, by CH2MHill, November 2001.

Throughout this peer review, the above document will be referred to as 'PSTA STSOC Report'.

The following document was utilized as supplemental information:

> "February 1999 to April 2001; PSTA Research and Demonstration Project, Phase 1 and 2 Summary Report", prepared for the South Florida Water Management District by CH2MHill, October 2001.

The PSTA Research and Demonstration Project included Phases 1 and 2, combined covering a period from February 1999 to April 2001:

- Phase 1: The 'experimental phase' included development of a workplan and experimental design, initial research in three experimental test cells, and construction / startup monitoring of research using 24 portable experimental PSTA mesocosms.
- Phase 2: The 'validation / optimization phase' included continuing research in PSTA test cells and in the portable experimental PSTA mesocosms, as well as design and observation during the District's construction of field-scale demonstration PSTAs immediately west of STA-2. During this phase the expanded PSTA operational database was used to further refine and calibrate the performance forecast model, and to develop design criteria for a full-scale PSTA system.

2.2 Work Objectives

The objective of this project was to conduct an independent review of, and provide comments on the design concept presented in the PSTA STSOC Report. The review includes the following major components:

1. Assess the validity of the conceptual design of full-scale facilities;
2. Review of the design assumptions; and
3. Verify that the design is conceptually correct and that there are no major errors in the conceptual design.

2.3 Peer Review Scope of Work

PB Water's peer review team evaluated, based on available information, whether the recommended solution(s) in the PSTA STSOC Report meet the intended use and performance goals. The team strived to review the document with regard to the following:

- Review the various design criteria, design assumptions, and technical approaches used by the designers and determine their appropriateness.
- Review the results of field and laboratory investigations during the demonstration stage, the facts and reasoning leading to the opinions, judgments, conclusions, and recommendations in the reports.
- Check for innovations, unproven technology, or untested materials. Study the design team's inquiries or research.
- Check that the design accounted for site-specific features of previous or adjacent construction, available utilities, proposed changes in utilities or access for transportation and other project requirements, and that is otherwise feasible.
- Check that appropriate design standards have been used as the basis for design.
- Check the calculations used in sizing the various basins and estimating their hydraulic characteristics, including seepage (where applicable).
- Check whether models adequately illustrate the flow through the facilities.
- Assess the validity of the assumed biological and ecological characteristics of the full-scale treatment facilities, including interior treatment and discharge quality (where applicable).
- Review of design assumptions, and computations documented in the Standards of Comparison Report and provide peer review comments.

3 PEER REVIEW TEAM

The peer review team was selected based on expertise in the general fields of ecology, wetland engineering, and natural system modeling. The team members were chosen by the SFWMD because of their knowledge and experience in the fields most closely related to biological treatment systems. The follow is a short summary of the peer review team.

ALEXANDER J. HORNE, Ph.D.
Dr. Horne has been the professor of Ecological Engineering at the Department of Civil & Environmental Engineering at the University of California since 1971. He is an expert in biological and chemical aspects of water and aquatic management including pollution in lakes, reservoirs, wetlands, rivers, streams, estuaries and the open ocean. He has studied lakes, reservoirs, streams, wetlands and oceans in Africa, Antarctica, Alaska, Europe, Australia, Asia,

and North and South America. He has been principal investigator in over 50 research projects and acted as a major consultant or advisor in over 300 water-related projects. Dr. Horne has 190+ publications in major scientific and engineering journals & reports including the most popular textbook on *Limnology* (the study of lakes, ponds, reservoirs, wetlands, rivers, streams, and estuaries).
Ph.D. 1969 - University of Dundee, Scotland: Limnology & Oceanography.
B.Sc. 1964 - University of Bristol, England: Biochemistry (Chemistry & Zoology options).

BIJAY K. PANIGRAHI, Ph.D., P.E., P.G.
Dr. Panigrahi has more than 20 years of experience in the specialty areas of hydrologic modeling, ground water modeling, statistical analyses, geohydrology and water resources engineering, including hydraulics, water quality assessment and modeling, monitoring network and water resources facility design. Dr. Panigrahi is an expert in model development and implementation. He has extensive knowledge in statistical evaluation of hydro-environmental data, including water quality, flow, and hydrometeorological records of both surface and ground water systems. Dr. Panigrahi has developed more than half a dozen models, has authored many publications and spoke many times at internationally recognized events in the water resources field.
Ph.D. Civil Engineering, Drexel University, USA, 1985
M.S. Civil Engineering & Geology, Oklahoma State University, USA, 1981
M.E. Hydraulics Engineering, Asian Institute of Technology, Thailand, 1978
B.S. Agricultural Engineering, Orissa University of Ag. & Tech., India, 1976

ARNOLD G. VAN DER VALK, Ph.D.
Dr. Van Der Valk has been Director of Iowa Lakeside Laboratory since 1994, and has been Professor in the Department of Botany at Iowa State University since 1982. Over the last 20 years, Dr. Van Der Valk has participated in and led scientific research around the world, and has taught in Ecology and Botany Programs at universities in South America, Europe and Australia. He teaches senior-level undergraduate course in plant ecology and graduate courses in wetland ecology, restoration ecology, population ecology, and community ecology. Here in Florida, Dr. Van Der Valk was recently a Visiting Eminent Scholar at the Florida Center for Environmental Studies in Palm Beach Gardens. Additionally, he is author or co-author of five books and close to one hundred wetland and ecology related publications.
B.Sc. 1968 - University of Windsor, Canada: Biology
M.Sc. 1970 - University of Alberta, Canada: Botany (Plant Ecology)
Ph.D. 1973 - N.C. State University: Botany (Plant Ecology)

4 PEER REVIEW

The PSTA STSOC Report outlines a methodology used to ultimately estimate full-scale conceptual designs with associated costs for a system downstream of STA-2. The methodology follows the STSOC Guidelines, so PSTA and other advanced treatment technologies evaluated through the same STSOC Guidelines may be compared in their performance to treat post-STA waters entering the Everglades. The methodology generally consisted of the following:

1. Identification of PSTA mesocosms and half-acre test cells to be used for STSOC analysis;
2. Implementation of the PSTA forecast model;
3. Simulation of TP concentration and flow for a given period-of-record;
4. Address STSOC data requirements; and

5. Develop conceptual designs for a full-scale PSTA and associated costs.

In order to assess the validity of the full-scale conceptual designs and cost estimates as developed under the STSOC Guidelines, the peer review team attended the Scientific Review Panel meeting held on December 13-14, 2001, and reviewed the documents described in Section 2.1. Below are our comments as they apply to the methods used to develop the full-scale conceptual designs and cost estimates along with design assumptions, and lastly, the validity of the conceptual design.

Conceptual Design of Full-Scale PSTA Facilities, Design Assumption, and Validity of the Conceptual Design

4.1 System Steady State

The STSOC Guidelines require data sets to be used from mature, stable PSTA cells. Results from the peat- and shellrock-based PSTA test cells were used for the STSOC analysis. In Field Scale Cell (FSC) –5, which was used for the STSOC analysis, macrophytes were still expanding their populations at the end of Phase 2. Macrophyte biomass made up a significant percentage of the overall biomass in this and other treatments. It is likely that the P sequestered in this treatment is simply in the accumulating biomass.

In a mature system that has reached steady state, the P/R ratio is expected to be less than 1. This means that there is more oxygen used in respiration (R) than released by photosynthesis (P) at any given time. The reason for this is that the mature system not only has respiratory uptake of oxygen due to the respiration of the periphyton but also by microorganisms and invertebrates that are the decomposers of dead periphyton. In fact, measurements of the P/R of periphyton mats in the Everglades are typically less than 1. Seasonal changes in light and temperatures, water level fluctuations, shading, etc. can all affect P/R ratios. The P/R ratio data from the PSTA studies are typically around 1. This suggests that the periphyton mats in these treatments had not yet reached a steady state, i.e., they were still growing.

If the periphyton mats in the PSTAs were not yet at a steady state then they are still accumulating biomass. If this is the case, then the measured removal rates of P may be higher than would be the case when the periphyton mats reach a steady state. When the mat reaches steady state, uptake of P by the mats will be lower then when the mats were still accumulating biomass. While the periphyton mat is still accumulating biomass, the amount of P it is taking up is increasing. When the periphyton mass reaches its maximum size, the P released by dying periphyton will be recycled within the mat and P uptake by the mat will drop. P uptake by the mat will drop to the level required to keep the mat at its steady state level. This steady state nutrient uptake level is the most reasonable estimate of how much P is being permanently sequestered (lost) by the mat over the long term. In other words, the P/R ratios measured in the PSTAs suggest that the rates of removal/uptake of P measured and used in the STSOC modeling effort were too high because they did not represent steady state rates.

Three caveats. One, steady state conditions for periphyton mats are never really reached because of seasonal changes in the rates of photosynthesis and respiration in these mats. The best estimate of the steady state condition would be an annual average based on a period of record of three or more years. These obviously are not available. Two, in any event, the length of the PSTA studies and the STSOC guidelines required use of data from much shorter periods. If P-removal had been based on estimates derived from studies that had been run longer, the STSOC results for the PSTAs might indicate that they will need to be even larger than the STSOC estimates. Three, the P/R ratio argument is at best suggestive of a problem with the P removal/uptake parameters used in the STSOC analyses. There is not enough data on P/R ratios in the Everglades or from the PSTAs to draw a definitive conclusion based solely on these data. The PSTA P/R ratios are also problematic because of the presence of significant macrophyte biomass in the PSTAs. It is the increasing macrophyte biomass in the PSTAs that is more indicative that the STSOC results are too optimistic.

Under P enriched conditions in the Everglades, periphyton communities are heterotrophic. If the periphyton/macrophytes never reached a steady state, we have no way to estimate the long-term sequestration rates of TP in a PSTA and no way of knowing what output levels of TP would be once periphyton/macrophyte biomass storage reaches steady-state conditions.

Recommendation: Hydrologically, we believe that the PSTA cells were stable, but from a biological, vegetative standpoint we do not believe the PSTA cells from which data were used were fully stabilized. We recommend that further study be done to determine the significance of biological steady state on biological performance, and ultimately on the PSTA full-scale prediction.

4.2 System Aging

The PSTA STSOC Report assumed for the PSTA Forecast Model that the "ability of PSTA to provide removal of TP from agricultural drainage waters is not expected to improve or decline with system age." This is a debatable assumption. All PSTAs appear to be accumulating sediment at a rapid rate. In other words, over their life expectancy, they will develop a P enriched organic substrate over their shellrock or limerock substrate. PSTAs with organic soils were not able to reduce outflow TP levels below 18 µg/L TP during their Optimal Performance Period (OPP). The poor performance of the peat-based systems was largely due to the release of P from previously farmed peats when they were reflooded. Nevertheless, until there is experimental evidence to the contrary, it would be prudent (more conservative) to assume some release of P will occur from the peat-based P-enriched sediments in PSTAs when they become periodically drawn down and reflooded, especially since the form in which the P is being sequestered in the sediments is unknown. Likewise, input concentrations of TP during these studies were low and output TP levels may increase with higher input levels. Higher hydraulic loadings are also likely to increase the concentrations of TP in the outflow. Under real-world operating conditions, the expected concentrations of TP from PSTA outflows are likely to be significantly higher than predicted. This does not take into account the operational problems and associated reduction in TP removal that will inevitably result from macrophyte control.

PSTAs with shellrock or limerock substrates under optimal operating conditions can reduce TP levels in their outflows significantly below that in their inflows. Nevertheless, for the reasons noted, it is far from certain that they will sustain these lower levels under real-world conditions over the 50-year life expectancy of a PSTA.

Recommendation: Provide support for the statement that PSTA performance is not expected to improve or decline with system age as a part of planned additional PSTA research. Further, a sensitivity analysis should be performed showing how P-removal / P outflow concentrations may vary with changes in PSTA operating conditions such as macrophyte control, changing water depth, or a change in substrate.

4.3 Modeling

The American Society of Consulting Engineers (ASCE) and the American Society for Testing Materials (ASTM) Technical Committees have identified a Standard Practice to report modeling results. The report should clearly describe the model assumptions, calibration, sensitivity analysis, and forecasting or simulation.

Calibration is performed on a set of assumptions to predict the measurements by adjusting the values of certain parameters (adjustable variables or calibration parameters). At the completion of calibration, sensitivity analysis is performed to determine the robustness of the calibrated model for each adjustable variable. In other words, sensitivity analysis is performed by changing the values of one variable over a certain range, while holding the other variables constant. This is likely to provide a narrow range of each variable within which the model is robust. Once robustness of the model is established, the model is then used for forecasting or simulation of various scenarios.

We could not locate a section describing the model limitations and assumptions. Since, the PSTA model is the basis for the conceptual design, it is absolutely necessary to know its capabilities and limitations, and to what extent it has been used for the STSOC analyses.

The PSTA model apparently has limitations in adequately representing the physical and hydraulic flow-through of water in full-scale PSTAs. A “Flow-Through System” is a system where inflow does not reside too long before it exits through the designed outlet. The effect of residence time is represented by the ‘tanks-in-series’ (TIS) factor. The PSTA model used a TIS factor equal to one for the conceptual design and cost estimates. This assumes that the cell is one continuously stirred tank reactor and that ‘tanks-in-series’ does not influence the design. However, the STSOC document states that TIS effect was significant (Page 4-7 of the STSOC report). Therefore, a TIS factor of 1 seems to be an incorrect assumption based on the tracer test results, aspect ratio of 1.5, and the full-scale size of the treatment cell. The sensitivity analyses of the PSTA model on the TIS parameter (no significant difference from 1 to 1.8) is inaccurately represented. This may be a limitation of the PSTA model itself. The implication of this assumption has considerable impact on the estimated footprint area and design cost. This may lead to an overestimate of the capital cost.

Sensitivity analyses performed on the rate constants (Section 3 of the Phase 1 and 2 Summary Report) did not determine the limits of the values within which the model is robust. In order to develop a confidence on the model application (forecasting for the present study), it is essential to establish the limits of the calibrated parameters and that forecasting be performed within such limits.

For a model to be validated prior to use for design forecasting, it is essential to document the mass balance of the system (water-W, phosphorus-P and biomass-B) within the controlled system (Test Cells with bottom liners).

Recommendation: Model PSTA performance with the Dynamic Model for Stormwater Treatment Areas (DMSTA) (Walker & Kadlec, 2000), which was developed as a platform for comparing ‘green’ P treatment technologies. We understand that the District will revisit PSTA-modeling now that the DMSTA is available.
Additionally, the following should be included in the PSTA STSOC Report:

1) Documentation of the model calibration process including assumptions and calibration parameters;

2) Documentation of model limitations and capabilities, and mass balance of three state variables (water, phosphorus, and biomass); and
3) Acceptable limits of adjustable variables or calibrated parameters established through sensitivity analyses.

4.4 Groundwater Seepage

The PSTA STSOC Report should document that the conceptual design and cost estimates are based on zero seepage loss. The relevance of the third paragraph on Page 4-12 of the STSOC Report stating the seepage rate referenced by Burns & McDonnell should be clarified. This paragraph indicates that the conceptual design has assumed a seepage rate greater than zero. If this is not true, then the document should clearly state so.

4.5 Presentation of Results

The report indicates that the research did not achieve the goal of 10 ppb. Instead, it achieved an average value of 12 ppb. The actual data ranged from 8 to 18 ppb over the Verification Performance Period (VPP). With such a small difference between the goal and the attained values, one aspect that should be examined is the measurement errors. It has been well established that measurement errors are present even with stringent quality assurance and quality control procedures.

Recommendation: Provide P-removal values and P-outflow concentrations with a confidence interval.

4.6 Macrophyte Management

Evidence from the reports, visits to various field PSTA demonstration sites, and knowledge from other sites indicate that a long-term pure PSTA system cannot be guaranteed in a full-scale project without control of large emergent plants, particularly cattails.

The results of both the Phase 1 and 2 studies show that macrophyte colonization of PSTAs can be very rapid. Since PSTAs will be downstream from STAs, PSTAs will have seeds from species that dominate the STAs entering them. Field and dosing studies in the Everglades also indicate that PSTAs will become dominated by macrophytes within a few years. Although the invasion by macrophytes was most pronounced in PSTA mesocosms with peat soil, it also occurred in those with shellrock and sand soils.

The PSTA STSOC Report acknowledges that some form of macrophyte management will be needed for PSTAs regardless of substrate. In fact, vegetation management will be required regularly, probably annually, throughout the 50-year life expectancy of a PSTA. Killing macrophytes in a PSTA will release the nutrients in the macrophytes, and it will require careful water management to prevent these nutrients from leaving the PSTA. Since periphyton will be at low levels when macrophyte treatment is needed, the PSTAs will have to be shut down for some period after macrophyte control ends to allow periphyton populations to regrow. Although the cost of macrophyte control has been considered in the STSOC analyses, the impact of macrophytes and macrophyte control on the design and operation of PSTAs has not been considered.

Recommendation: To more accurately evaluate the operational flexibility and costs of PSTAs, additional research should more precisely determine the following:
- The level of macrophyte management needed (frequency and percentage of PSTA area);
- The most appropriate method of management, including mechanical removal (mowing, crushing, etc.) and burning;
- The effect of macrophyte management on P-removal; and
- Costs associated with macrophyte management.

We understand that management of macrophytes will be addressed in upcoming field scale tests.

4.7 Biosludge Management

The conceptual design assumes that PSTAs are a relatively low-management treatment option. This is contrary to the research program, which indicated that in addition to control of macrophytes, the accumulation of 3 to 4 feet of P-enriched biosludge is a management challenge, especially over a large footprint.

The design assumes no harvesting of biomass or sediments. Handling of biosludge is a management and technical challenge, and therefore needs further study. The treatment operation is expected to continue for 50 years. The accumulated sediments are very likely to release the stored P especially during high flow times. On Page 4-13 of the STSOC report, the water depth increases from an average value of 1.14 feet to 5 feet for a short duration. The increase in water depth is more than 100% in a short time period during maximum flow conditions. Such an increase in stage is likely to cause perturbation and thus vertical mixing of the accumulated sediments containing the stored P. In addition, during the PSTA research study, the output P concentration was measured at higher than the input concentration and this was attributed to the presence of an alligator in the test cell during the test period. A large number of alligators are likely to be present in a full-scale system. Thus, increasing the potential for release of stored P from the accumulated sediments.

It was estimated that 3-4 feet of P-contaminated peat will accumulate over 50 years. This measurement was made using simple sediment traps and may over- or underestimate accumulation. The design freeboard for the additional capacity is limited and sludge may become the massive problem it is for many other pollution removal methods such as activated sludge, alum precipitation of phosphate, or flocculate in drinking water treatment systems. Peat removal would be prohibitively expensive but some means such as drying and oxidizing would work if the system were initially designed with enough flexibility. Natural oxidation or oxidation by burning or some modified disturbance of dry peat all could be utilized. Drying out for long periods would also make the management of competing, emergent vegetation more feasible without the need to use pesticides.

Recommendation: Additional research should be done to determine the amount of sediment accumulation in PSTAs, its effect on P-removal, as well as methods to remove the sediment should it adversely affect PSTA performance. If the accumulation does not affect P-removal, increasing the design freeboard of PSTAs may be adequate. Sediment removal methods considered should include: physically digging the sediment out and hauling it off, natural oxidation (dry-out) or oxidation by burning.

4.8 Operational Flexibility

The statements that full-scale PSTAs are highly flexible to operate, and that PSTA performance is not significantly affected by natural incidents such as floods, droughts, fires and storms, needs more support.

Recommendation: Perform additional PSTA research to determine effects of macrophyte and biosludge management, flooding, dry-outs, burning and uprooting on PSTA operations.

4.9 PSTA Conceptual Design Cost Estimates

Capital costs for PSTAs seem in line with experience. The only potentially fatal issue for PSTAs might be the limerock, which amounts to 80% of the capital cost, because it is unknown how its performance on the long term will be. The limerock may behave erratically over time and have an unpredictable effect on P-removal.

Recommendation: As indicated above, costs related to the following should be more adequately addressed:

- Macrophyte and biosludge management;
- Long-term effect of the substrate on PSTA performance and cost;
- Effects of natural PSTA disturbances such as varying P-inflows and hydraulic loading, flooding, drought, storms, and burning.

4.10 Levee Design

The conceptual design assumptions presented in Exhibit 4-8 appears satisfactory except for the following specifications. The top widths of the external and internal levees are too narrow. The treatment system along with the levees has a minimum design life of 50 years (the treatment period). These levees are long and need regular maintenance and vehicular access. Therefore, the top widths should be wider than assumed.

Recommendation: Increase the top width of the PSTA levees to allow for vehicle access.

4.11 Phosphorus Budget

We recommend preparing a P-budget for PSTA systems. An annual P budget would be a way to determine if P sequestration is occurring. It should be feasible to accurately estimate TP in inflows (including wet and dry fallout), outflows, and storage in the biomass (algal and macrophyte) at the end of a study. The difference between inflows and outflows plus water column storage would be an estimate of storage in the sediments (plus sampling and analytical errors), which may be difficult to measure directly because of high background P levels. In any case, a P budget is a good way to determine the overall reliability of the studies done.

5 CONCLUSIONS

Following the STSOC Guidelines, the PSTA STSOC Report addressed the ten quantitative and qualitative STSOC Guideline criteria. However, some issues are brought to attention by our peer review team:

1) Biological steady-state does not seem to be reached for the PSTA cells from which data sets were used for forecasting;
2) These data sets were extrapolated outside the model's limits regarding hydraulic loading, phosphorus inflow concentration and water depth of the PSTA test systems;
3) Model limitations may have resulted in over- or underestimating PSTA size and cost;
4) Macrophyte and residuals management are not adequately accounted for.

The peer review team's main recommendations are as follows:

- Re-evaluate the biological stability of PSTA systems used to provide modeling and calibration data sets;
- Re-address modeling with the now available DMSTA model;
- Perform a P/R ratio analysis (oxygen used in PSTA photosynthesis versus oxygen used in PSTA respiration) to determine steady-state for PSTAs;
- Provide quantitative information on anticipated side streams (macrophyte and biosludge management). This will be important information evaluating PSTA operational flexibility and cost. Additionally, the effect of the proposed side-stream management options on PSTA effluent TP concentrations should be described;
- Gain more insight in long-term behavior of the substrate. If this is to be limerock, what effect will the forming of an organic substrate have on TP removal and PSTA operational costs and flexibility?